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AUTOMOTIVE EXHAUST GAS ANALYZERS 1974.



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Automotive Exhaust Gas Analyzers

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Report EPS 3-AP-74-5

Air Pollution
Control Directorate
November 1974

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AUTOMOTIVE EXHAUST GAS ANALYZERS*

Mobile Sources Division

Abatement and Compliance Branch

Air Pollution Control Directorate

Report EPS 3-AP-74-5

November 1974

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ABSTRACT

A survey of automotive exhaust gas analyzers was conducted by questionnaire to evaluate available equipment and solicit user experience. From a questionnaire completed by 13 manufacturers of automotive exhaust gas analyzers, data on instrumentation available, operational characteristics, cost, and service provided were obtained. This information may be compared with data obtained from a second questionnaire completed by 21 users of automotive exhaust gas analyzers who indicated instrumentation in use, reliability, ease of operation, and availability of service. A method for grading the analyzers is also included.

RÉSUMÉ

On a fait une enquête sur les analyseurs de gaz d'échappement des véhicules automobiles, afin d'évaluer le matériel disponible et de faire appel à l'expérience des usagers. À partir d'un questionnaire rempli par 13 fabricants d'analyseurs de gaz, on a obtenu des renseignements sur l'instrumentation disponible, les caractéristiques opérationnelles, le coût et le service donné. Ces renseignements peuvent être comparés aux résultats qu'on a obtenus à partir d'un second questionnaire rempli par 21 usagers d'analyseurs de gaz qui ont indiqué les instruments utilisés, leur fiabilité, leur facilité d'utilisation et le service qu'ils pouvaient obtenir. On donne aussi une méthode permettant de classer ou de comparer les analyseurs entre eux.

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1 INTRODUCTION

1.1 Background

Exhaust emissions from motor vehicles have been identified as a significant contributor to urban air pollution problems. Internal combustion engines used in motor vehicles produce carbon monoxide, unburned hydrocarbons, oxides of nitrogen, carbon dioxide, and particulate matter, which may be released to the atmosphere. A wide range of equipment has been developed to analyze motor vehicle exhaust emissions under different conditions. These systems vary from complex analyzers with constant-volume samplers which monitor compliance with federal motor vehicle standards to simple low-cost garage-type analyzers which assist in automotive tune-ups.

1.2 Exhaust Emission Tests

Three parameters may be used to define typical emission tests: engine load, type of analyzer, and data utilization. When the engine from which exhaust is being analyzed is loaded, a dynamometer is required to perform the analysis. The analyzer may either be a complete system having a constant-volume sampler or a simple garage-type instrument analyzing undiluted samples. The data obtained may be required to monitor for compliance or for diagnosis of engine problems. These factors interact with one another to determine choice of suitable analyzers.

Two exhaust emission tests widely in use are the idle test and the key mode test. The idle test is performed with the vehicle in neutral, all accessories off, and the engine at normal operating temperature. No dynamometer is needed and the sampling procedure is relatively simple. The undiluted exhaust stream is analyzed for carbon monoxide and unburned hydrocarbons using simple garage-type equipment. The resulting data can be used to monitor compliance or to adjust the carburetor idle settings and reduce emissions. The key mode test is a type of diagnostic test performed under three or four operating conditions designed to check the carburetor at idle, normal main jet operation, and full power, and the timing and ignition system at basic and advanced conditions. The engine is operated at varying load; a dynamometer is required, and analysis can be done either with a constant-volume sampler system or with a garage-type instrument using undiluted samples. The resulting data are normally used diagnostically to assist in performing engine maintenance.

Other engine diagnostic tests combining exhaust emission analyzers and engine analyzer equipment have also been devised. The results are used to indicate maintenance required on the engine.

2 METHODOLOGY

2.1 General

Recent studies (1-5) have presented information on the technical performance of exhaust emission analyzers. This study, however, was undertaken to determine the availability of analyzers suitable for vehicle emission inspection and diagnostic purposes, to assess reliability, cost, availability of service, and operational characteristics of each analyzer, and to define a method for comparing these instruments.

2.2 Method of Approach

Because many of the commercially available analyzers have been technically evaluated in other studies (1-7), emphasis in this study was placed on obtaining information on users' experience and comparing it with manufacturers' claims. Two questionnaires were therefore designed, one for manufacturers of exhaust gas analyzers and a second for users of these instruments. Appendix I contains copies of these questionnaires. The manufacturers' questionnaire was sent to the following companies:

Allan Electric Mfg. & Equipment of Canada Ltd.
Analygas Systems Ltd.
Applied Power Automotive Canada Ltd.
Autoscan (U.S.)
Beckman Process Instrument Div.
CAN/AM Instruments Ltd.
Chrysler Corporation (U.S.)
Detector Electronics Inc. (U.S.)
J.W. Ellis Industries
MSA Canada Ltd.
Peerless Instrument Company of Canada
Robert Bosch (Canada) Ltd.
Suntester Equipment (Central Ltd.)

Responses were received from all 13 companies contacted. A second questionnaire was sent to 44 users of exhaust gas analyzers who responded as follows:

User	Response rate
Domestic automobile and truck distributors	7/8
Imported automobile distributors	6/13
Miscellaneous	8/23

Section 3 presents technical data on exhaust gas analyzers obtained from the manufacturers' questionnaire and existing reports (1-11). Section 4 presents field experience data obtained from the users' questionnaire.

3 TECHNICAL DATA

3.1 Types of Analyzers

3.1.1 Flame Ionization Detectors (FID). These detectors operate on the principle that a hydrogen-air flame contains a negligible number of ions. However, when trace amounts of an organic compound such as hydrocarbons (HC) are introduced into the flame, a large number of ions are produced. If a polarized voltage is impressed across the burner jet and an adjacent collector, an ion migration will occur, producing a current proportional to the number of ions and hence to the hydrocarbon concentration present in the flame. This small current can be measured by a sensitive electrometer.

The sensitivity of the FID to a specific hydrocarbon is generally proportional to the number of carbon atoms passing through the flame in a given period of time. Thus, the FID will have twice the output for a given flow rate of hexane (C_6H_{14}) as for the same flow rate of propane (C_3H_8). Its output will also be doubled if the flow rate of the hydrocarbon being analyzed is doubled. Therefore, it is important to maintain the same sample flow rate during sample analysis as was used when calibrating the instrument. The FID output must also be referenced to some standard hydrocarbon, such as parts per million normal hexane or parts per million carbon. FID analyzers are selective only to the hydrocarbon in the gas sample; carbon monoxide, carbon dioxide, oxides of nitrogen (NO_x), water, and nitrogen have no effect. However, oxygen in the exhaust may alter the FID reading slightly (usually less than 5%), depending upon the burner fuel composition (i.e. pure hydrogen, hydrogen-nitrogen mixture, or hydrogen-helium mixture) and the ratio of flow rates of burner fuel and exhaust sample to the burner. Properly used, the FID provides a rapid, accurate, and continuous means for measuring total hydrocarbon concentration in an exhaust stream with concentrations as low as 1 ppb.

3.1.2 Mass Spectrometry. Mass spectrometers are primarily used as laboratory instruments. Their means of analysis is based on the behavior of charged particles in electromagnetic fields. Use of the mass spectrometer in combustion work has been largely restricted to flame studies, but it can also be applied to exhaust measurements.

3.1.3 Chemiluminescent Analyzer. This instrument is based on the chemiluminescent radiation in the red and infrared spectral regions resulting from the reaction between nitrogen oxide (NO) and ozone (O_3). This radiation can be detected with a suitable photomultiplier tube, and the output can be amplified and displayed. Concentrations of nitrogen oxide from 0.2 to at least 100 ppm can be continuously measured with 5% accuracy.

3.1.4 Electrochemical Analyzer. This type of analyzer finds application in detecting the amount of oxygen within an exhaust stream. Oxygen in the exhaust stream passing across the detector diffuses through a Teflon membrane into the electrolyte within the detector and is reduced at the cathode. This reduction of oxygen results in a current flow that is proportional to the partial pressure of oxygen in the sample. This current is then amplified and displayed as a percentage of oxygen.

3.1.5 Thermal Conductivity Analyzer. The measurement of the thermal conductivity of a binary or quasi-binary gas mixture can be used to indicate the ratio of the two components of the binary mixture. This method is of limited accuracy and is used only in the simplest type of analyzers.

3.1.6 Catalytic Combustion Analyzer. In this analyzer measured quantities of the exhaust sample and clean air are mixed and passed over a noble-metal catalyst filament. The catalytic combustion that takes place heats the filament to a temperature proportional to the hydrocarbon of the gas sample. This method is not widely used in current equipment. One currently available HC/CO analyzer utilizes the ultraviolet radiation emitted during catalytic combustion as a measure of HC/CO concentration.

3.1.7 Gas Chromatography. The gas chromatograph provides a display of the separation of components of a mixture rather than an indication of the concentration of a specific compound within a mixture. It allows each compound to be identified and quantitatively measured. Although it may provide the most nearly complete analysis available of an engine exhaust stream, it may be time-consuming and is restricted to batch sampling procedures. As with dispersive spectroscopic analyzers, gas chromatographs are primarily laboratory tools.

3.1.8 Spectroscopic Analyzer. By far the most widely used analytical method is spectroscopic analysis. The spectrum showing light absorbed as a function of frequency (or wavelength) by a compound is different for each compound. Spectroscopic analyzers operate on the principle that the quantity of light absorbed by a compound in a sample cell is proportional to the concentration of the compound in the cell. These analyzers may be divided into the two general categories of dispersive and nondispersive.

3.1.8.1 Dispersive analyzer. Dispersive analyzers utilize only a narrow 'dispersed' frequency of the light spectrum to analyze a compound. As this type of analyzer is primarily a laboratory tool and not commonly used in engine-exhaust emissions work, no further discussion of dispersive analyzers will be given here.

3.1.8.2 Nondispersive infrared analyzer. Nondispersive infrared (NDIR) analyzers are the most commonly used instruments for exhaust emission analysis and are the federally accepted standard for vehicle certification through the 1971 model year for measuring exhaust hydrocarbons, carbon monoxide, and carbon dioxide.

Since the maximum absorption of light radiation for each compound usually occurs at a specific wavelength or frequency, the NDIR analyzer is able to use the gas or vapor of the compound

under analysis to detect itself. In this type of analyzer two infrared sources are interrupted simultaneously by an optical chopper. Radiation from these sources passes in parallel paths through a reference cell and a sample cell to opposite sides of a microphone detector. The reference cell contains essentially none of the compound to be analyzed, while the sample cell holds the sample containing the compound to be analyzed. The microphone detector is a closed container holding only the gas or vapor of the compound of interest. It is divided into two equal volumes by a thin metal diaphragm. Figure 1 illustrates two typical layouts for microphone detector analyzers.

In operation, the radiant energy from one source passes through the reference cell unchanged, while that from the other source is diminished at the absorption frequency of the compound of interest by an amount proportional to its concentration in the sample cell. If unequal amounts of energy at the absorption frequency of the vaporized compound in the detector reach the opposite ends of the detector, the two volumes will be heated and will expand unequally, which causes a displacement of the metal diaphragm toward the side of reduced energy. The diaphragm displacement frequency will be equal to the chopper frequency. The moving diaphragm causes a capacitance difference between itself and a fixed probe. This creates a signal which may be amplified and displayed on a meter or a recorder.

Errors with this type of detector occur when there are components in the sample stream that absorb radiation at the same frequency as does the detector gas. If such components are known to exist, it may be possible to minimize their effect by placing a filter cell containing the interfering components in series with the sample cell. If the analyzer zero is set with this relatively large quantity of interfering gas, the small additional quantities of the interfering gas in the sample stream will have little effect on the detector output.

The NDIR analyzer works particularly well for gases such as carbon monoxide and carbon dioxide which have clear infrared-absorption peaks that are not overlapped by peaks of the other components in the sample. It should be noted, however, that NDIR analyzers sensitized to normal hexane for the purpose of detecting hydrocarbons respond equally well to other paraffinic hydrocarbons (excepting methane), but not to olefins, acetylenes, or aromatics. For this reason, the NDIR-indicated value of hydrocarbons in vehicle exhausts is multiplied by 1.8 to correct it to the total unburned hydrocarbon as measured by an FID analyzer in the same exhaust stream.

Recent developments in optical infrared filters and solid state detectors have yielded many new configurations for infrared analyzers. Typical optical filters and solid state detector designs are shown in Figure 2.

Although the microphone detector analyzer uses the infrared-absorbing gas as an infrared selector and detector, the solid state detectors use an optical filter for obtaining selectivity. The filter isolates a particular infrared region, depending on the design specifications. Typical instruments use a variety of standard infrared detection sources such as thermopiles, thermistors, and lead selenium cells. The advantage of the optical filter detector is its longer life expectancy and long-term discrimination against carbon dioxide and water interference at expected in-use vehicle

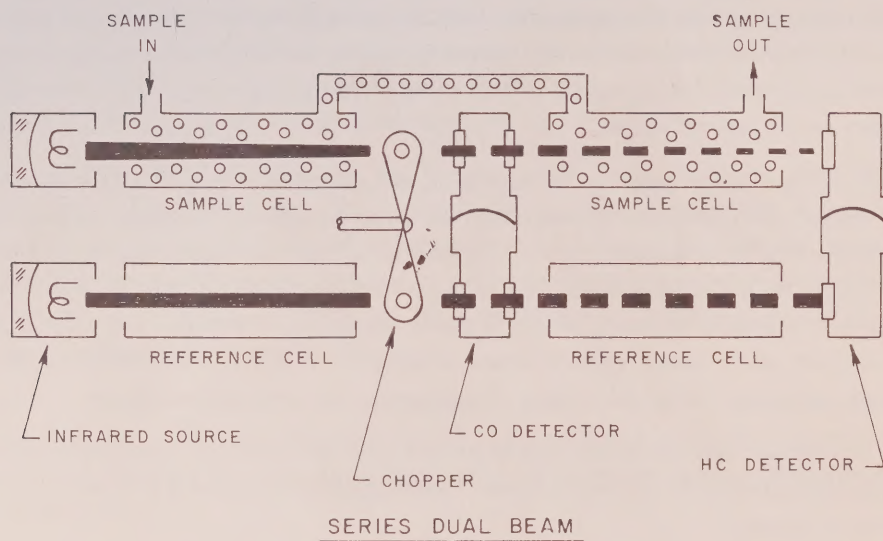
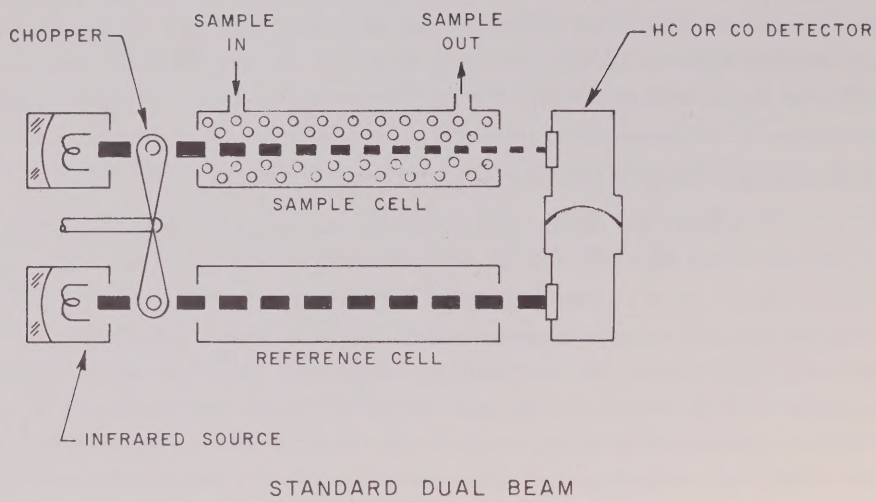
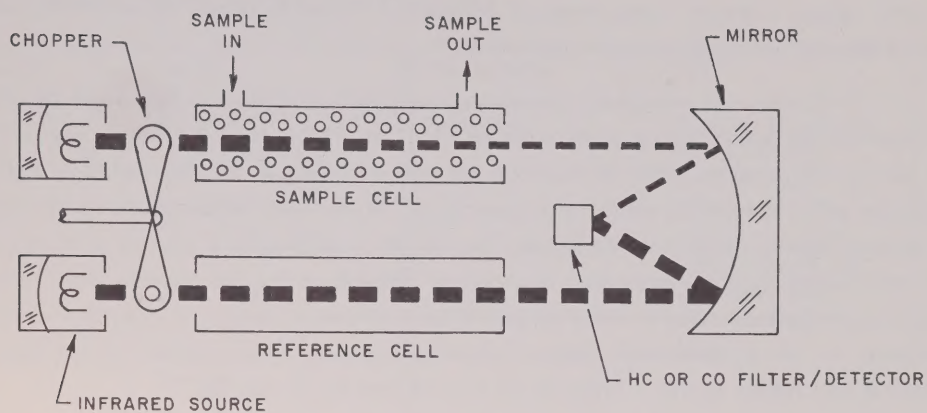
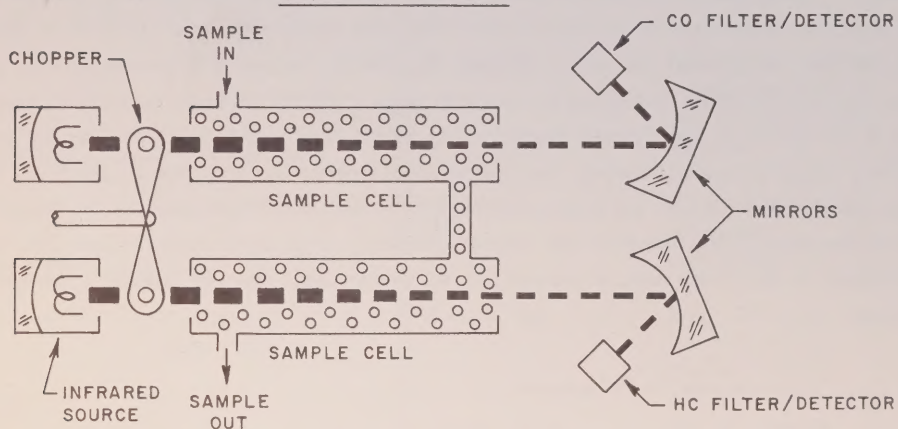


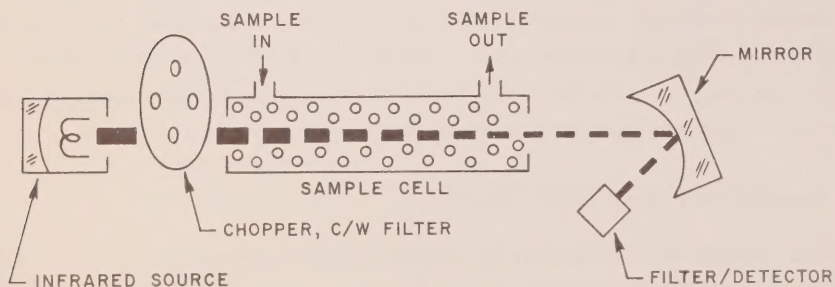
FIGURE I INFRARED ANALYZER CONFIGURATIONS USING MICROPHONE DETECTORS



(A) DUAL BEAM



(B) SINGLE BEAM



(C) CHOPPER FILTER

FIGURE 2 INFRARED ANALYZER CONFIGURATIONS USING OPTICAL FILTERS AND SOLID STATE DETECTORS

emission ranges. However, carbon monoxide sensitivity is limited by carbon dioxide interference for ranges expected for newly manufactured vehicles.

In Figure 2, design A illustrates a dual-beam analyzer in which a gas detector is replaced with an optical filter and solid state detector. The infrared beam is reflected from a mirror so that parallel radiation passes through the cell and is focused on the filter-detector. Design B illustrates the same analyzer without the reference cell. In this case, the zero point on the analyzer is the total infrared energy from the source. This method is advantageous because of its simplicity, but zero stability is highly dependent upon source temperature and cell thermostating. Design C shows an alternative method in which the optical filter reference is placed in the chopper so that the reference cell can be eliminated. Carbon monoxide, hydrocarbon, and carbon dioxide filters are placed in the chopper so that a single bench may be used for all analyses.

3.1.8.3 Nondispersive ultraviolet analyzer. Nondispersive ultraviolet analyzers (NDUV) have been made for the detection of nitrogen dioxide. They work on the same basic principle as does the NDIR analyzer, except that the optical chopper alternatively interrupts the energy source to the reference and sample cells. The source is a tungsten lamp, which provides light in the near-ultraviolet range of the spectrum. The detector consists of an optical filter, selected to pass only the desired frequency range of source radiation, and a phototube sensitive to light of that frequency range. Absorption of light energy in this frequency range by the component of interest in the sample cell, with no absorption in the reference cell, causes a pulsating output from the phototube. This signal, proportional to the component of interest in the sample cell, may be suitably amplified and displayed.

3.2 Performance Specifications

Current portable analyzer design has concentrated on the nondirectional infrared principle described in section 3.1.8.2 and illustrated in Figures 1 and 2. Each manufacturer has adopted a somewhat different approach, and as a result, the configuration and operational characteristics of each make of instrument differ. A recent study (5) has attempted to define a more rational approach by developing the set of desirable performance specifications shown in Table 1. Some but not all of these specifications are met by commercially available equipment.

3.3 Commercially Available Equipment

The following section describes the range of models of exhaust gas analyzers available from each of the 13 manufacturers contacted.

3.3.1 Allen Analyzer. The Canadian distributor for Allen analyzers is Allen Electric Manufacturing and Equipment Company of Canada Ltd., 3250 Lenworth Drive, Mississauga, Ontario. They currently offer a Model 23-060 exhaust emission analyzer for measuring hydrocarbons and carbon monoxide concentrations in exhaust gas, and engine analyzer systems Models 15-090 and 18-090 incorporating a HC/CO analyzer unit. The dealer list price for the 23-060 analyzer is

TABLE 1 TARGET PERFORMANCE SPECIFICATIONS

Characteristic	Target	Characteristic	Target
CO range	0-10%	Calibration	Capable of external gas calibration; rapid internal calibration with controls on front panel; capable of calibration with probe inserted in tailpipe
Scale div.	0.2 above 1%		
HC range	0-2000 ppm		
Scale div.	20 or 50 ppm		
Meters	Min. size 8 in. on a side; no static interference		
Accuracy		Flow meter or alarm	Equipped
Below mid range	$\pm 0.25\%$ CO, ± 50 ppm HC		
Above mid range	$\pm 0.5\%$ CO, ± 100 ppm HC	Condensate trap	Capable of complete condensate removal; self dumping; easy cleanout
Repeatability	Within accuracy limits for min. 6 months	Particulate filter	Easily replaceable; infrequent replacement
Warm-up time	< 30 min	Sample line	Min. 20 ft; low HC adsorpt.; flexible, strong
Response time	10 s for 90% reading	Sample probe	30 in. flexible metal hose or reinforced joint where flexible hose joins rigid pipe; device to hold probe inside tailpipe
Purge time	< 30 s	Moveable cart	Equipped
Stability			
Zero setting	< 2% full scale drift in 8 h		
Span setting	< 2% full scale drift in 8 h		
Max. adjustment	two per day; hold to targets with frequent temp. changes		
Sensitivity to line voltage	None to normal fluctuation		

\$2895; the list prices for the 15-090 and 18-090 models are not relevant as they include the cost for complete engine analysis instrumentation.

3.3.2 Autoscan Analyzer. The Canadian distributor for Autoscan products is Byron King, 94 Millwich Drive, Toronto. They currently offer a Model 705 and a Model 710 HC/CO analyzer and also a 4000 Series which includes related engine analyzer equipment. The dealer list price for the Model 705 is \$2858 and for the 4000 Series \$3195. The 710 price is not relevant as this model is not currently being imported into Canada.

3.3.3 Beckman Analyzer. The Canadian distributor for Beckman analyzers is Beckman Instruments, Inc., 901 Oxford St., Toronto. They currently offer a Model 590 HC/CO vehicle exhaust analyzer for \$1950.

3.3.4 Bosch Analyzer. The Canadian distributor for Bosch analyzers is Robert Bosch (Canada) Ltd., 33 Atomic Avenue, Toronto. They currently offer a Model EFAW-173 CO tester at \$400 and are introducing a new Model EDAW 289 CO-HC analyzer for approximately \$2800.

3.3.5 Chrysler Analyzer. The Chrysler Model III CO/HC/CO₂ (optional) analyzer is marketed in Canada by Chrysler Canada AUTOPAR at a suggested list price of \$2450.

3.3.6 Detector Electronics. The Canadian distributor for the Detector Electronics UVE21 analyzer is Levitt Safety Ltd., 33 Laird Drive, Toronto. This analyzer was formerly marketed by Honeywell. The current list price, including taxes and duty, is \$1250.

3.3.7 Ecologic Analyzer. The Canadian distributor for the Ecologic line of analyzers is Can-Am Instruments Ltd., 1938 Mattawa Ave., Mississauga, Ontario. The Model R1740 and the Model 5500 analyzers will be introduced in late 1974 and list prices are not yet available.

3.3.8 Ford Analyzer. Ford of Canada distributes to its dealers a line of Ford Rotunda engine analyzers which incorporate HC/CO emission analyzers (Ford Model Nos. ARE-1097 and ARE-23-060). These analyzers are manufactured for Ford and marketed independently by Allen Electric Manufacturing and Equipment Co. of Canada Ltd. Further information on the Ford analyzers is given in section 3.3.1.

3.3.9 Hartman and Braun Analyzer. The Canadian distributor for the Hartman and Braun analyzers is J.W. Ellis Industries, 105 Progress Ave., Unit 58, Scarborough, Ontario. The current list price for the CGCOT2 model is \$1500.

3.3.10 Marquette Analyzer. The Canadian distributor for Marquette analyzers is Applied Power Automotive Canada Ltd., 305 Progress Ave., Scarborough. They currently distribute a Model 42-153 CO/HC analyzer with a list price of \$1750.

3.3.11 Peerless Analyzer. The Peerless Instrument Company of Canada, 67 Industrial Road, Richmond Hill, Ontario, will be distributing a Model 660 gas analyzer which lists at \$1995.

3.3.12 MSA Analyzer. MSA Canada, 148 Norfinch Drive, Downsview, Ontario is currently considering the distribution of a HC/CO analyzer which will list at \$1500-\$2000.

3.3.13 Olson Horiba Analyzer. The Canadian distributor for Olson Horiba equipment is Analygas Systems Ltd., 220 Midland Ave., Scarborough, Ontario. They currently offer a Mexa 200 CO analyzer at \$1325, a Mexa 300 Model CO/HC analyzer for approximately \$2300, and a GSM 300 HC/CO analyzer for approximately \$2950. New models being introduced are the Mexa-400, which is capable of measuring CO₂ concentrations of up to 16% in addition to HC and CO, and a Mexa 500 HC/CO/CO₂/NO_x analyzer.

3.3.14 Sun Analyzer. The Canadian distributor for Sun analyzers is Suntester Equipment (Canada) Ltd., 915 Oxford St., Toronto. They currently offer a Model EPA 75 HC/CO tester for approximately \$2700.

3.4 Summary of Operational Characteristics

Tables 2 and 3 present a summary of the characteristics for the analyzers considered in this report. These data have been extracted from manufacturer's brochures and from published technical reports (1-10).

3.5 Custom Analyzers/Future Developments

Both Olson Horiba and Marquette have indicated that they will be offering a new analyzer this year. The Olson Horiba instrument will be a NO/NO_x meter selling for approximately \$2000-\$3000; the Marquette instrument will be a CO/HC analyzer.

Both Sun and Olson Horiba have designed and fabricated special 'custom' analyzer systems for state and municipal governments in the United States. Olson Horiba recently developed a portable CO/HC meter for the California Highway Patrol, used for spot checking emissions at existing safety inspection stations. The analyzer, designated CHP-300, is in a self-contained trailer and is battery powered. Sun has also developed a portable HC/CO measuring system for the California State Highway Patrol. This system, installed in a trailer, was designed around the EPA-75 HC/CO analyzer, and is called the EPA-75P. The system includes a DC/AC power supply module and a remote meter panel. The California State Highway Patrol is currently using 63 EPA-75P analyzers. Sun recently developed a HC/CO analyzer for the State of New Jersey inspection stations. The design was based on the EET-910 model, and 125 systems were purchased by New Jersey. The systems were designed to provide rapid measurement of exhaust emissions at idle in existing safety inspection lanes. Sun also developed a special analyzer, the VETS-75, based on its model EPA-75, for the city of Chicago. The system was designed to monitor hydrocarbon, carbon monoxide, and carbon dioxide levels at idle and at 2250 engine rpm. The system is computerized and contains a remote sensing tachometer.

4 USERS' EXPERIENCE DATA

4.1 General

As indicated in section 2.2, one purpose of this study was to obtain information on users' experience with exhaust gas analyzers using data from questionnaires (see Appendix I) sent to 44 users identified in section 2.3. The questionnaire provided information on makes of analyzers in use (questions 1 and 2), experience (question 3), service (questions 4 - 8), and operation (questions 9 - 15).

4.2 Summary

Table 4 indicates the total number of each make of analyzer reported in the user questionnaires. Many of the analyzers discussed in this report were not mentioned on the returned questionnaires because they have only recently or have not yet been introduced into the Canadian market. The data on these questionnaires were analyzed and are summarized in Table 5. Additional weighting was applied to data from users with lengthy experience and/or a large number of instruments. In cases where the sample size is small (see Table 4) the results rely on the experience of a few users, and must be judiciously interpreted.

5 INSTRUMENT GRADING

The grading of analyzers requires the definition of a set of criteria and a weighting factor for each individual criterion. Each application may have a slightly different set of criteria and weighting factors. For example, a portable research analyzer, a garage diagnostic analyzer, and an inspection station analyzer will require different performance criteria. Tables 2, 3, and 5 provide data for potential users to choose the most suitable analyzer for their particular application. Canadian distributors who may be contacted if further information is required are given in section 3.3.

6 CONCLUSION

Changes that have occurred since the previous analyzer evaluation studies (1 - 5) indicate that the analyzer market is still developing rapidly. Because of the growth in this area, the data presented in Tables 2, 3, and 5 must be interpreted judiciously, especially in the area of service. New organizations which have been set up specifically to market exhaust gas analyzers cannot initially offer the same service network as do older established firms that are adding exhaust gas analyzers to their product line.

Because continued improvement of instrumentation and availability of service is anticipated, frequent review will be required to keep abreast of new developments.

TABLE 2 ANALYZER CONFIGURATION DATA

Manufacturer	Model No.	Gases Measured				Analyzer type and configuration	Flow indicator	Condensate trap	Part filter	Remote meter	Length Samp. line (ft)	Weight (lb)	Cost (\$)
		HC	CO	CO ₂	NO								
Allen	23-060	X	X			NDIR-F-2		X	X	X	20	70	2895
Allen ²	18-090	X	X			NDIR-F-2	X	X	X		30	37	N/A
Autoscan	705	X	X			NDIR-F-2	X		X		N/A	71	2860
Autoscan	710	X	X			NDIR-F-2	X		X		N/A	71	N/A
Autoscan ²	4000	X	X			NDIR-F-2	X		X		N/A	N/A	N/A
Beckman	590	X	X			NDIR-F-1	X	X	X		25	85	1950
Bosch	EFAW 173		X			HOC		X	X		N/A	N/A	400
Bosch	EFAW 289	X	X			NDIR-M-2	X	X	X		N/A	45	2750
Chrysler ³	III	X	X	X		NDIR-F-1		X			20	20	2450
Detector													
	UVE21	X	X			UECD		X	X		N/A	N/A	1250
Electronics													
Ecologic ⁴	RI 740	X	X	X		NDIR-M-2		X	X		N/A	35	N/A
Ecologic ⁵	5500		X	X		NDIR-M-2		X	X		N/A	22	N/A
Ford ²	ARE1097	X	X			NDIR-F-2	X	X	X		12	N/A	N/A
Hartman-Braun	CGCOT2		X			NDIR	N/A ⁶	X	X		N/A	25	1500
Marquette	42-153	X	X			NDIR-F-1		X	X		30	60	1750
Peerless	660	X	X										
MSA		X	X			NDIR-M-1	X					33	1800
Olson Horiba	Mexa 200		X				X	X	X		N/A	16	1325
Olson Horiba	Mexa 300	X	X			NDIR-M-2	X	X	X		N/A	25	2300
Olson Horiba	GSM 300	X	X			NDIR-M-2	X	X	X	X	N/A	125	2950
Olson Horiba	Mexa 400	X	X	X		NDIR-M-2	X	X	X		N/A	30	N/A
Olson Horiba	Mexa 500	X	X	X	X	NDIR-M-2	X	X	X	X	20		N/A
Sun	EPA 75	X	X			NDIR-F-2	X	X	X		25	90	2690

¹NDIR, nondispersive infrared; UECD, ultraviolet emission combustion detector; HOC, heat of combustion; F, optical filter solid state detector; M, microphone detector; 1, single beam; and 2, dual beam.

²Engine diagnostic instrumentation included.

³Optional push button display for CO₂.

⁴Optional CO/HC or CO/CO₂ measurement.

⁵Optional CO or CO₂ measurement.

⁶Not available.

TABLE 3 ANALYZER OPERATIONAL DATA

Manufacturer	Range		Accuracy(% full scale)				Warm-up (min)	Response (s)	Drift (5)	Operating temp. (°F)	Calib. methods
	Model	No. HC(ppm)	CO(%)	CO ₂ (%)	NO(ppm)	HC	CO	CO ₂	NO		
Allen	23-060	2000	10			5	5		5	2/24 h	M, G
Allen	18-090	2000	10			3	3		10	2/24 h	M, G
Autoscan	705	2000	10			2	2		7		E, G
Autoscan	710	2000	10			2	2		7		G
Autoscan	4000	2000	10			2	2		7		E, G
Beckman	590	2000	10			3	3		5	35-110	E, G
Bosch	EFAW 173						10				
Bosch	EFAW 289	2000	10			3	3		10	1/24 h	E
Chrysler ¹	III	2000	10	15		2	2		5	30-115	E, G
Detector Electronics	UVE21		6			5	5		10	40-90	E, G
Ecologic ²	RI 740	2000	10	20		5	5	5	7	32-105	M
Ecologic ³	5500		12	20			5		10	32-105	M, G
Ford	ARE1097	2000	10								
Hartman-Braun	CGCOT2		10				5		2	32-95	
Marquette	42-153	2000	10			5	5		10	32-122	M, G
Peerless	660	2000	10			3	3				M
MSA	1500		10						7		E
Olsen Horiba	Mexa 200		10				2		5		G
Olsen Horiba	Mexa 300	1500	10			5	5		7		E, G
Olsen Horiba	GSM 300	1500	10			5	5		7		G, E
Olsen Horiba	Mexa 400	250	2	16		5	5	5	7		G, E
Olsen Horiba	Mexa 500	1000	10	16	4000						
Sun	EPA 75	2000	10			25	25		7	32-120	E, G

¹ Optional push button display for CO₂ on CO meter.² Optional CO/HC or CO/CO₂ measurement.³ Optional CO or CO₂ measurement.

TABLE 4 ANALYZERS REPORTED IN USER QUESTIONNAIRES

Manufacturer	Model No.	No. of instruments in use
Allen	23-060	4
Allen	18-090	0
Autoscan ¹	705	4
Autoscan	710	1
Autoscan	4000	0
Beckman	590	1
Bosch	EFAW 173	2
Bosch	EFAW 289	0
Chrysler	III	2
Detector Electronics	UVE21	0
Ecologic	RI 740	0
Ecologic	5500	0
Ford	ARE1097	0
Hartman-Braun		0
Marquette	42-153	2
Peerless	660	0
MSA		0
Olson Horiba	Mexa 200	3
Olson Horiba ¹	Mexa 300	8
Olson Horiba	GSM 300	4
Olson Horiba	Mexa 400	0
Olson Horiba	Mexa 500	0
Sun ¹	EPA 75	72

¹ California Highway Patrol has a total of four Autoscan Model 705, four Olson Horiba Mexa 300, and 63 Sun Model EPA-75.

TABLE 5 SUMMARY OF USER DATA

Manufacturer	Model No.	Service data			Operational data						
		Freq. of maint.	Freq. of repair	Average downtime	Repair service	Simple operation	Instr. manual	'Hangup' problem	Easy to zero	Freq. of calib.	Response time adequate
Allen	23-060	nil	1/year	2 weeks	satis.	yes	avg.	no	yes	N/A	yes
Autoscan	705	1/month	1/3 months	2 days	unsatis.	yes	fair	yes	yes	daily	yes
Autoscan	710	N/A ¹	N/A	N/A	N/A	yes	good	no	yes	daily	yes
Beckman	590	nil	1/3 months	1 month	N/A	yes	fair	yes	yes	N/A	no
Bosch	EFAW 173	1/day	1/year	nil	satis.	yes	good	no	yes	hourly	yes
Chrysler	III	nil	nil	N/A	N/A	yes	avg.	yes	yes	N/A	yes
Marquette	42-153	nil	1/3 months	2 days	satis.	fair	avg.	no	fair	daily	no
Olson Horiba	Mexa 200	1/day	nil	2 weeks	satis.	yes	good	no	yes	daily	no
Olson Horiba	Mexa 300	1/day	1/3 months	2 days	unsatis.	fair	good	yes	yes	daily	yes
Olson Horiba	GSM 300	1/day	1/6 months	2 weeks	fair	fair	good	yes	yes	daily	yes
Sun	EPA 75	1/month	nil	1 day	satis.	yes	good	yes	yes	daily	yes

¹ N/A, not available.

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4. Gannoe, R.E., Riley, C.R., and Frink, D.W., *Gas Monitoring Equipment Investigation*, Battelle Memorial Institute Report AD730509 (1971).
5. Panzer, J., *Idle Emissions Testing*, SAE Paper No. 720937 (1972).
6. Booy, R.R., *Some Instrumentation and Techniques for Measuring Emissions*, SAE Paper No. 710482 (1971).
7. Peck, W.H., and Harmelink, M.D., *Transportation Air Pollution*, Ontario Department of Highways, Report No. RR169 (1969).
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10. Horowitz, J., 'Inspection and Maintenance for Reducing Automobile Emissions', *J. Air Pollut. Control Assoc.*, 23 (4) (Apr. 1973).
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APPENDIX I
QUESTIONNAIRES

FORM LETTER SENT TO MANUFACTURERS AND USERS



HOVEY & ASSOCIATES LTD.
VEHICLE SYSTEMS ENGINEERING

2378 HOLLY LANE
OTTAWA, ONTARIO
K1V 7P1
(613) 731-7090

18 February 1974

Mr. John Doe
26 Appleford Drive
Orillia, Ontario
F3B 8K2

Dear Sir;

Our firm has recently been awarded a contract to evaluate the state-of-the-art in exhaust gas analyzers for the Department of the Environment. The results of the study will be used to assist DOE contacts with the selection of suitable equipment. Non-proprietary information on both present and proposed instruments is being solicited from both manufacturers and users of automotive exhaust gas analyzers which are suitable for idle, key mode, and diagnostic testing.

Your firm has been identified as a manufacturer/user of exhaust gas analyzers and your assistance is requested in filling out and returning the enclosed questionnaire at your earliest convenience, as only questionnaires received by FEBRUARY 28TH can be utilized in the final report.

In closing I would like to thank you for your prompt attention in this matter.

Yours truly

Dr. N.D. Eryou, P.Eng.
Director of Operations

NDE/sp

Encl.

MANUFACTURERS' QUESTIONNAIRE

C316 EXHAUST GAS ANALYZER REPORT MANUFACTURERS' DATA

- 1) Please enclose technical data and list price data (fob Toronto, taxes out, duties included) for your current automotive exhaust gas analyzer product line. Ensure that sufficient technical data is included to fully describe the principle of operation of each analyzer. Any available non-proprietary information on new instrumentation which will be marketed within 3 years should also be submitted.
- 2) Please define the availability of repair service for your product line by identifying your service representatives in each province and indicate if the analyzers must be sent out of Canada for major repair.
- 3) Please forward data on the recommended preventative maintenance schedules for your instrumentation, and the frequency-of-repair record for each model.

USERS' QUESTIONNAIRE

Question	Instr. No. 1	Instr. No. 2	Instr. No. 3	Instr. No. 4	Instr. No. 5
1. Manufacturers' name.					
2. Model number.					
3. Length of service.					
4. Frequency of preventative maintenance (filter changes, etc).					
5. Frequency of repair.					
6. Location of the nearest service depot.					
7. Average downtime during servicing.					
8. Has the repair service been satisfactory?					
9. Is the analyzer easy to operate?					
10. Are the instruction manuals adequate?					
11. Have you experienced 'hang up' problems in the sampling section of the analyzer?					
12. Is the analyzer easy to zero?					
13. How long does the analyzer hold calibration?					
14. Does the warm-up time correspond to the manufacturer's claim?					
15. Is the response time suitable for your application?					

16. Please rank your instruments
according to the following
parameters: (i.e. 1 = best,
2 = next best, etc)

16a. easiest to operate

16b. most rugged & portable

16c. least preventative maintenance

16d. easiest to calibrate

16e. fewest hang up problems

16f. easiest to zero

Additional Comments:

Canada - E.P.S.		
E.P.S. 3-AP-74-5		
AUTHOR	Automotive exhaust	
TITLE	gas analyzers	
DATE DUE	BORROWER'S NAME	DATE RET'D

UNIVERSITY OF TORONTO
INSTITUTE FOR ENVIRONMENTAL STUDIES

